Greening the roadway: an assimilated planning approach and techniques based on spatiality

Tamosi Bhattacharya

Intercontinental Consultants and Technocrats Private Limited,
A-8, Green Park, New delhi-110016, India
Email: tamosi.dse@gmail.com
Email: tamosi.bhattacharya@ictonline.com

Abstract: The special attribute of environmental parameters having no spatial or temporal boundary is what caters to the inter-relationship between various kinds and patterns of adjoining land uses. Understanding of the magnitude and directional flow of impact has given rise to an interlinked conceptual base to plan for a greener roadway in an Indian perspective. The inter-linkages as established in this study are between road runoff and liquid waste from adjacent settlements; vehicular emission of greenhouse gas, air pollutants and noise and exposure of road side dwellers to the same due to lack of adequate sink or abatement measures; huge amount of ground water extraction for road construction at a time and conflicts with local users, etc. These parallel moving issues have been addressed through simultaneous multi-approach (SMA) Solution. It involves meticulous spatial arrangement of paved and unpaved surface within the right of way (RoW) and use of integrated management system for tapping road runoff and creating emission sink; utilisation of special material combination for reduction in air pollutants; innovative techniques and simultaneous approaches to manage liquid and solid waste generated in the vicinity; devise reparation activities to compensate for usage of natural resources, etc.

Keywords: simultaneous multi-approach solution; bio-retention; carbon footprint; percolation pond; spatial planning; greener roads.

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Biographical notes: Tamosi Bhattacharya holds a Master's in Environment Planning and is currently working with a consultancy firm. She is responsible for conducting environmental studies for various infrastructure projects like roads, airports, railway lines, railway stations and building construction. Her research focuses on innovative environment conforming approaches for successful completion of live projects.

1 Introduction

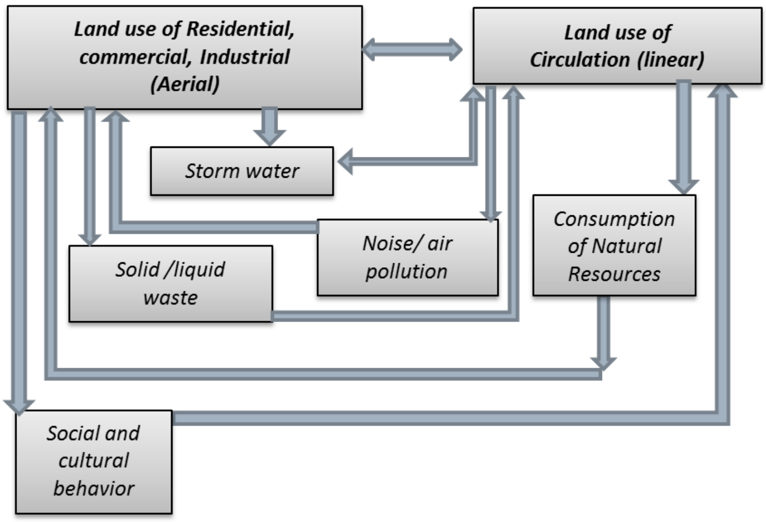
The road section of six-lane National Highway 1 from Kundli Chowk (Delhi Border) at Km 29.3 to Panipat at Km 86 within the National Capital Region (of Delhi) is one of the heavily operated roads in India with annual average daily traffic (AADT) of 90,571 passenger car unit (PCU). It is a part of Delhi-Ambala-Jalandhar-Amritsar-Pakistan Border road. The study road stretch lies in the state of Haryana in India. The huge amount of traffic can be attributed to the emergence of extensive uses of industries and townships apart from other village turned towns and commercial establishments. With the development of Master Plan 2021 for the major towns of Kundli-Sonepat, Murthal, Ganaur, Samalkha and Panipat, the whole road section falls within the controlled areas (Land use is controlled by the planning authority of the town and land is reserved for its future expansion). Wherein, 60 metres on either side of the Right of Way has been reserved for green belts. Out of the total area of 60 metres on either side, 237.45 ha (35%) is agricultural that is not logical to convert into green belt; 125.5 ha (18%) is already built up and left over 317.45 ha (46%) of land has a lot of industrial and township proposals coming up. Given the rapid pace of urbanisation and sheer scarcity of land, creating this natural buffer to vehicular noise, sink for air pollution, greenhouse gas emission and manage storm water nuisance, does not look feasible.

This study has been conducted based on both primary and secondary data. After collection of data a detailed analysis was done to identify the specific issues to be addressed and possibility of applying greener interventions and its degree of effectiveness. Each identified issue was then studied in detail to suggest counter measures and their designs. One season monitoring has been done at six locations for air quality, five for surface water quality, four for ground water quality and five locations (on both side of road) for noise levels as per Indian Standards. California Line source Dispersion Model (CALINE 4) developed by Lakes Environment has been used to predict air pollution concentration level along with Traffic Noise Model (TNM 2.5) developed by Federal Highway Administration (FHWA) for noise level modelling. Carbon emission has been calculated using Calculator for Harmonized Assessment and Normalization of Greenhouse gas Emissions for Roads (CHANGER) developed by International Road Federation (IRF). Land use analysis has been done using ArcGIS, version 9.3 developed by Environmental Systems Research Institute (ESRI), California based on topo sheets, satellite imageries and ground truthing. Designs have been prepared in AutoCad, 2012.

The Inter-Linking Concept of Greener Highway has been developed in this study to assess the magnitude and directional flow of impact of various issues arising out of a road. This concept has been taken further as a basis for evolving feasible greener interventions. Storm water generates two way impacts in the form of water logging along the road creating space crunch for both road users and road side dwellers. Noise and air pollution and carbon emission generated due to vehicular movement produces one way impact on the aerial/point land users since their exposure time is all throughout the day and night. Whereas, the highway users (through traffic) are exposed for a very less period to the aerial/point source pollution. Aerial pollution sources refers to those extended over a considerable area like a city or town generating storm/waste water along the road and point sources refers to those present at a point like industries generating air pollution. Exposure to pollution also depends on the presence of amount of pollution sink, particularly in terms of vegetation. Construction of roadways, like any other activity, creates immediate cavity into the natural resource stores in the surrounding, generating one way impact. For example, land for widening of road, land for borrow areas, soil, sand, aggregates, gravels, water, fuel that has a far flung ecological footprint. In terms of socio-cultural behaviour, prominent one side impact due to road side dwellers is observed which is reflected through unauthorised interventions of local people and nature of commercial establishments. For example, in case of NH1, unauthorised median openings and unsafe way of road crossing reflects the irresponsible behaviour of people who can make way for themselves by altering the road design as per convenience. Further, the presence of liquor shops along the roadway lures drivers, especially to drink and drive leading to around 346 accidents annually in the 56.7 Km stretch of project road. Solid and liquid wastes generated from residential, commercial and industrial wastes are dumped by road side creating nuisance in terms of hygiene and aesthetics (especially near eating joints) and space crunch. Diagrammatic representation of the inter linkage is shown in Figure 1.

In light of the same, this paper intends to evolve a comprehensive spatial plan (planning over the space to manage different activities or uses) accommodating a simultaneous multi approach system to manage waste in one's own land and compensate for the use of natural resources. Here is an attempt to explore the environment friendly mechanism and techniques of up grading an existing road.

Figure 1 Inter-linking concept of greener highway (see online version for colours)



2 Environmental profile of project area

2.1 Storm water

With critical rainfall intensity (Ic) of 14.11 cm/h, time of concentration (tc) for 500 m being 33 minutes, the project area can generate peak runoff of 0.19 m^3. Annual storm water generation potential of the project area is around 20.78 lakh cum. The existing drainage system has coverage of only 9 km (7.9%) out of 113.4 km both side without any storm water tapping arrangement and only 2% of the project area is unpaved. This leads to accumulation of water along the road, both within and outside the RoW. Biological Oxygen Demand exceeds by 25 times, in the adjoining ponds and water logged areas, above 3 mg/l, the limit of Class of Water-B (Water fit for organised outdoor bathing) as per Central Pollution Control Board's Water Quality Criteria. Chemical Oxygen Demand is at the range of 163 mg/l to 495 mg/l along with presence of Escherichia Coli at the range of 14 to 64 MPN/100 ml and Total Coliform at a range of 200 to 900 MPN/100 ml. It exhibits mixing of the road runoff with sewage and industrial effluents firstly, contaminating it and secondly, increasing the volume of water logging creating inconvenience for traffic movement, road side dwellers, shopkeepers and pedestrians. This also exposes ground water aquifers to similar contamination. However, it has been less evident due to lower depth to water table (20 mbgl in post monsoon) and over exploited aquifers with the Ground Water development stage ranging from 138% to 186% (Central Ground Water Board, 2008).

2.2 Natural resource cavity

Natural resource cavity refers to the loss created due to extraction of natural resources for any anthropogenic activity. Immediate natural resource cavity is created due to the construction of road, with its impact being spatially far flung. The project road of 56.7 km (six-lane) during construction had used 42 lakh metric ton of soil that is equivalent to 140 ha of land. Water required for construction of the road is equivalent to the annual requirement of 15 villagers.

2.3 Carbon footprint and sequestration

The cumulative embodied and direct Greenhouse gas (GHG) emission, i.e., the carbon footprint of the construction materials used is 5.74 lakh ton CO_2-eq (six times more than naturally occurring atmospheric carbon) as calculated using CHANGER. Emission factors of various types of materials are given in the calculator by default. The quantity of material and distance of source from site for the materials are entered to get the resultant GHG emission using Formula (1) (Zammataro, 2011). Quality and reliability of the databases and the calculation procedures has been analysed and validated by the LAVOC (Traffic Facilities Laboratory) of the Swiss Federal Institute of Technology.

$$Emissions_{(embodies+direct)} = S_i * emission\ factor \tag{1}$$

where

S_i source $(A * I)_I$

A activity level

I intensity.

Vehicular emission during the operation period is 756.64 ton CO_2-eq/day (Central Pollution Control Board and Automotive Research Association of India, 2007). Share of diesel is computed to be the highest with 81% or 43,489.5 kg/km followed by petrol with a share of 17% or 8,930.3 kg/km. Concentrated Natural Gas has the lowest share of 2% or 1,026.7 kg/km. The share of diesel (56%) vehicles is the highest followed by petrol (38%) and CNG (6%) directly proportionate to the amount of emission from these fuels. On an average the emission from petrol, diesel and clean fuel contributes to 2.2 kg/l or 2200 mg/m^3 which is three times or 301.7% (Tans, 2009) more than the naturally occurring amount of carbon dioxide. Vehicular emission has been calculated using emission factors given by the Automotive Research Association of India and Central

Pollution Control Board based on the factors of mode, vintage year and fuel type of vehicle. Mode wise count of AADT as generated from primary survey was first segregated on the basis of fuel and vintage year. Fuel type and vintage year data was collected from fuel station survey. Later number of vehicles of a particular mode, vintage year and fuel type has been multiplied with the corresponding CO_2 emission factor and summation of the emission generated by all the modes of vehicles was done.

Green vegetation acts as good carbon sink, but the present project area consists of only 7.3 ha sequestering 583.46 ton CO_2-eq/year (Akbari et al., 1992; US Department of Energy, Energy Information Administration, 1998) which is only 0.21% of the annual vehicular emission. With this rate, an area of 2,764.3 hectare would be required to create a sink for total vehicular emission, which would not be possible due to land constraints. To calculate sequestration, the number of trees were first segregated on the basis of their diameter at chest height from ground and then multiplied with their corresponding emission factors as given by US Department of Energy, Energy Information Administration (1998).

2.4 Ambient air pollution

The monitoring results show that PM_{10} and $PM_{2.5}$ are exceeding the permissible limits by an average of 17 $\mu g/m^3$ and 3.5 $\mu g/m^3$ near the automobile industries and values in rest of the stretch are approaching the permissible limit. Methane is present in trace amount below the instrument detectable limit. Carbon monoxide has also been found to be below the permissible limit.

Maximum cumulative ground level concentration (GLC) of CO predicted using CALINE 4 for the base year is 0.2 parts per million (ppm), for 2015 its 0.3 ppm and for 2045 its 1.6 ppm at a distance of 15 m, 20m and 35 m from the centre line respectively. In the year 2045 it reaches beyond right of way by 5 m where the first row of commercial cum residential building lies. The predicted value is expected to remain below the permissible limit of 2 ppm (Central Pollution Control Board, 2009). However, there is an increase in spatial coverage and increasing trend observed over the projected years.

2.5 Ambient noise pollution

Vehicular noise as monitored ranges from Leq 62 to 72 dB (A) [> permissible limit of 55 dB (A)] in the day time and Leq 54 to 63 dB(A) (> permissible limit of 45) at night. Since the first line of building comprises of residential, commercial and industrial uses, permissible limits of residential zone (Ministry of Environment and Forest and Climate Change, 2000) is considered as it is the most sensitive amongst the three. Noise level beyond the college boundary (9 m from paved surface) is 23 dB(A) more than the permissible Day time Leq of 50 dB(A). A hospital at km 31.600 in the right hand side (RHS) has its boundary wall at a distance of 8 m from road edge and receives 12 dB(A) more noise than that permissible in the day time and 17 dB(A) more than that permissible at night.

It is required to reduce the noise level using on road treatment by 12 dB(A) by 2035–2045 in Kundli; by 24 dB(A) in Murthal, Ganaur and Samalkha; by 15 dB(A) in Bahalgarh, the main junctions with flyovers as predicted using Federal of Highway Administration-TNM (FHWA-TNM), for meeting day time permissible limit of 55 dB(A). Corresponding reduction will take place at night time also.

2.6 Solid and liquid wastes

The informal eating joints (dhabas) are an integral part of any highways providing eating options for the road users. Along the present road stretch, there are 32 dhabas generating solid waste of 33.86 kg/day on an average. Out of it, 44% consists of organic wastes. On an average 3.5 KLD of waste water is generated from each dhaba. These are disposed on the adjoining land abutting the road's right of way creating unhygienic environment and land degradation.

3 The simultaneous multi-approach solution

In the given institutional framework of India, the interlinked issues are handled by different executing/implementing authorities functioning independently. Hence, a simultaneous multi-approach (SMA) solution needs to be followed (Figure 2), so as to carry out multiple tasks simultaneously for the project road and surrounding uses, considering it as a planning unit with direct and indirect influence areas identified. The interventions can be divided based on the implementing authorities, viz.,

a *Road-based*, i.e., direct project interventions within project area, reparation activities outside project area and corporate social responsibility (CSR) under the jurisdiction of road project proponent.

b *Local body-based*, i.e., Solid waste and sewage management project identification for villages and towns by project proponent to be implemented by the local bodies

c *Industrial or commercial establishments and developed townships*, i.e., persuasion with State Pollution Control Board (SPCB) for debarring identified commercial and industrial units from disposing off their waste within the right of way.

This paper shall focus on the road-based direct and indirect interventions to be taken up by the project proponent. Presently, the common practice in India to manage road runoff is through rain water harvesting (RWH) pits as per guidelines of the Ministry of Road Transport and Highways (Ministry of Road Transport and Highways, 2013). Road side plantation is done as per Indian Road Congress' Special Publication (Indian Roads Congress, 2009). On road noise barriers are designed as per MoRTH Guidelines for Expressway (Ministry of Road Transport and Highways, 2010). Building treatment for noise is done as per National Building Code (Bureau of Indian Standards, 2005). Alternative pavement technologies like warm mix, cold mix, asphalt recycling are more commonly being used. Solid and liquid waste management options for roads have not yet attracted much attention in terms of actual practice. Clean fuel or CNG is being promoted for reducing air pollution but is majorly concentrated in bigger cities. With reference to the present context this paper has focused on preparing a comprehensive plan for a greener road wherein certain best practices has been modified to fit to the roads planning unit in Indian perspective.

In the course of this study few provisions have been identified that are required to be made in the policy and the planning level, viz., Alternative modes like rapid rail, multilevel roadways or similar way outs shall be decided in the regional planning level as it is not feasible to keep on widening the road with ever increasing vehicular traffic, given the paucity of land. Lower registration costs, lower toll tax and availability of clean fuel stations in settlements along the National Highway shall encourage use of clean fuel vehicles. Out of sight out of mind principle shall be applied by the local bodies collaborating with road project proponent for liquor shops by way of which liquor shops shall not be allowed in the first row of building use. The intervening space between the liquor shop and Right of Way shall have some other commercial use to cut the view.

4 Greener options for road-based interventions

4.1 Storm water management

Referring to the site conditions and space availability, low impact development bio-retention system (LID-BRS) has been designed for the Left hand side (LHS) and groundwater recharge pit for the RHS of the road (Figure 3). LID-BRS is not yet a common practice in India especially for roads.

Figure 2 Simultaneous multiple approach for greener roadways (see online version for colours)

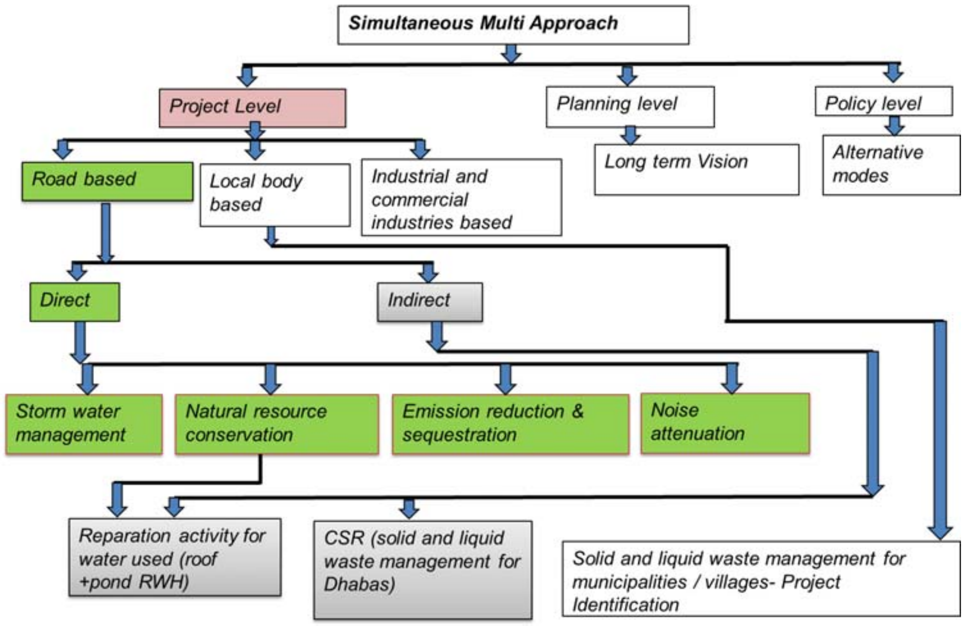
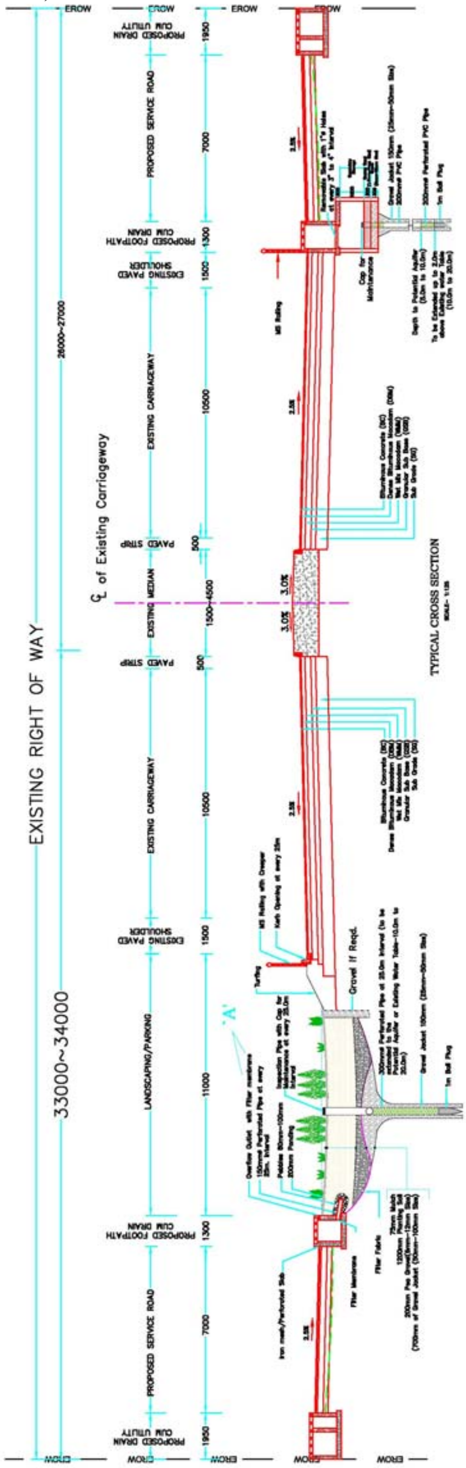


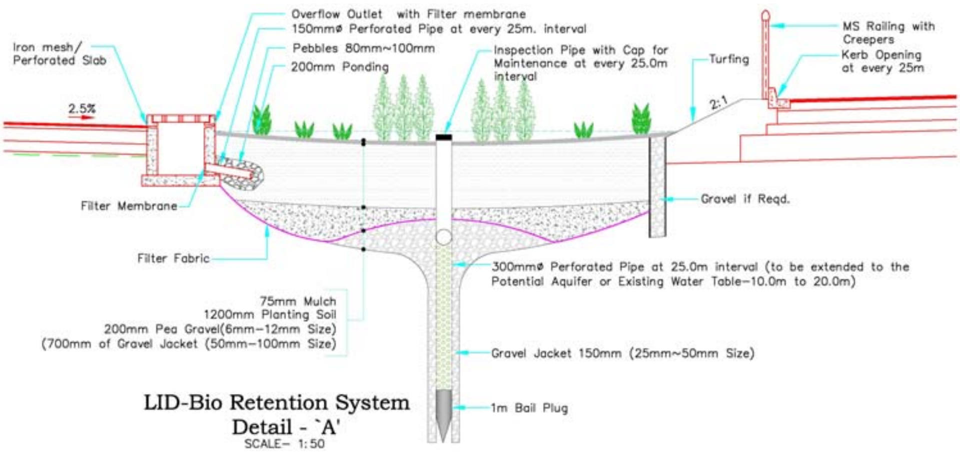
Figure 3 Cross-section showing placement of storm water management systems (see online version for colours)



4.2 Bio-retention system

LID-BRS is an integrated storm water management system that facilitates 80% tapping of rainfall within its catchment area, groundwater recharge of 33% and rest is available for irrigation. It saves on land as it combines plantation area and treatment facility for road runoff and conventional drain can be used as immediate linear backup storage. Moreover, placement of the system for 11.5 m width along the road length between left main carriageway and left service road leads to physical segregation from road side solid and liquid wastes. The system consists of a pre-treatment system and layers starting from 0.2 m of ponding area underlain with mulch layer of 0.075 m, planting soil of 1.2 m depth, pea gravel diaphragm of 0.1 to 0.2 m depth, a filter fabric with minimum permeability rate of 3 m/min to 6 m/min, 0.5 m gravel jacket around a 0.3 m perforated (non-perforated where it encounters unsaturated soil layer) under drain pipe. PVC pipe to be laid horizontally as under drain and extended to a depth of 2m above the ground water table at every 500 m. Bail plug of 1m shall be placed at the end of the vertical perforated PVC pipe to avoid back suction from the aquifer. The pipe shall be perforated at every 0.15 m with three holes evenly placed along the pipe circumference. Above the vertical downward pipe a blind/non-perforated pipe shall be extended vertically till the top and capped, to act as an inspection pipe (Department of Conservation and Recreation, 2010). In this study, BRS has been designed exclusively in linear pattern for the project road.

Figure 4 Cross-section of LID-BRS designed for the project road (LHS) (see online version for colours)



The runoff from LHS service road shall be first directed and stored in the covered drain through perforated slab or iron rod mesh to maintain a flow rate of minimum 8 m/min to reduce maintenance of the drain as well as inlets to BRS. It is then directed into the bio-retention ponding area through a sub-surface bio-swale pre-treatment inlet of pebble (0.08 to 0.1 m diameter) jacketed perforated PVC pipe with 0.15 m diameter. The bio-swale is designed to be at the bottom of the drain with a filter mesh (minimum 3 µm pore size and flow rate of 440 mL/min/cm^2) on the mouth of the pipe. From main carriageway, runoff shall be directed as sheet flow over grassed embankment for removal of debris and dirt (slope > 2% but < 20%) through kerb openings at every 25 m interval, to the ponding area. Cross section is given in Figure 4). The standing time for the ponded water shall not be more than 3.3 days and evaporation loss during the rainy season (July to September) is estimated to be negative (–0.005 to –0.2 lts/hr/m^2).

The ponding area shall not be deeper than 0.2 m, otherwise plants or shrubs would not be able to survive. The maximum volume per running meter is 1.6 m^3 (0.2 × 8 × 1) for ponding storage, which is more than the actual volume of 0.88 m3 per running meter with the maximum discharge of 0.56 m^3/s. The excess water shall be run out into the adjacent drain with an outlet at a height of 0.2 m from the mulch layer. The mulch layer should be well-aged, stockpiled or stored for at least 12 months; uniform in colour; and free of other materials, such as weed seeds, soil, roots, etc. (Alderete and Scharff, 2005). Eucalyptus trees are present in abundance within the right of way and a share is likely to be cut for the design improvement which can be used. Purpose of the organic layer is to filter finer particles from the storm water runoff and maintain soil moisture in the planting soil (Claytor and Schueler, 1996). The planting material shall be native to site and tree species like acacia auriculifornis, Bauhinia racemosa (kachnar), Azadiracta indica, pongamia puinata (karanj), terminalia arjuna (arjuna), cordia dichotoma (lasooda), syzigium cumini (jamun) can be planted in the central row and shrubs like salix species (laila majnu), calistimon species (bottle brush) in the outer rows and creepers like quis quails indica (malti), pyrostea verista (bridal creeper) can be grown on the railings at the outer edge.

BRS is a maintenance intensive system and hence the success of the design depends largely on effective maintenance viz., Removal of debris from inlet and outlets after every major storm; watering in case of no rainfall; Inspection of planting soil is required monthly during monsoon and that of planting material, at least twice during growing season; Trees and shrubs shall be pruned annually and the mulch layer shall be replaced in every three years (Department of Conservation and Recreation, 2010).

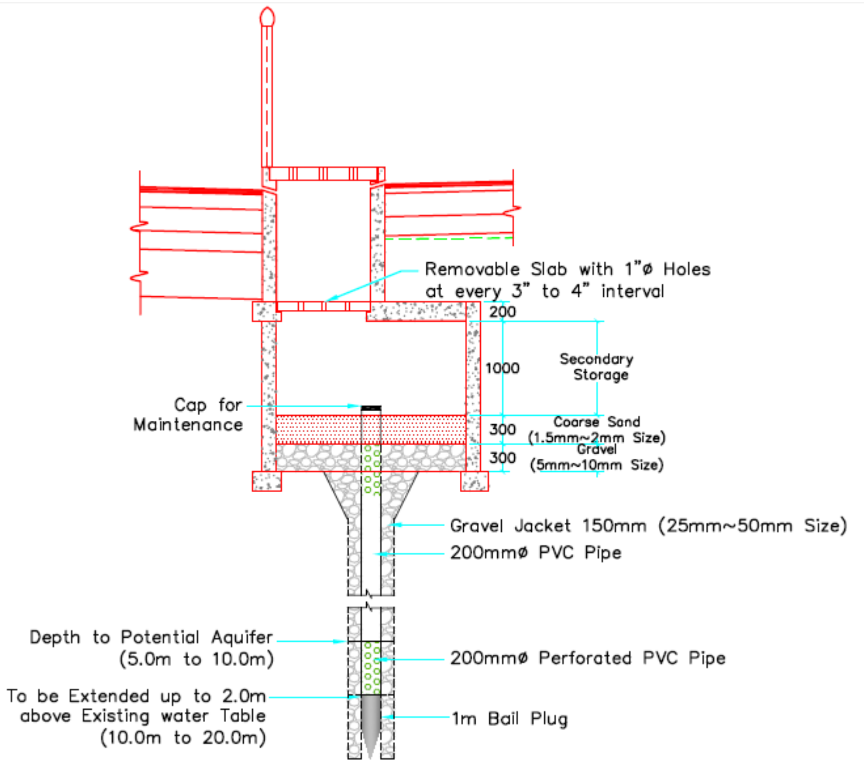
4.3 Groundwater recharge pit

Due to space crunch, in the RHS, ground water recharge pits (GWRP) are designed and placed beneath the drain at every suitable interval, to direct the runoff from RHS main carriageway and service road to the aquifer. The drain shall be designed with storage capacity for the maximum possible runoff (0.48 m^3/s). The inlets to drain shall have either perforated concrete slab or iron rod mesh with a flow rate of minimum 8 m/min. This will help segregate the debris/leaves, etc., and prevent the drain from getting choked. Since the GWRP is placed beneath the drain, a secondary storage area has been designed to save the first layer of sand from being diluted and get carried away. Dimension of the pit is designed to be 3 m × 2 m. A filter mesh with descending order of sieve opening shall be provided to remove the debris and silt to maximum extent. This shall be separated from the initial storage by removable perforated slab (4 to 6 mm diameter perforations at an interval of 50 to 80mm) and shall maintain a flow rate lesser than that of the inlet to drain to prevent wash away of filter media. Any back flow shall be taken care of by the initial storage drain (cross section is shown in Figure 5). The filter media is designed to have hydraulic conductivity (k) of 5 to 8 m/day that would take 6.24 hours for the water to infiltrate through the 1.1 m deep filter media and 0.15 m wide gravel jacket allowing time for filtration of suspended particles, oil, and grease. This system also needs maintenance in the form of debris removal after every major storm and cleanup annually (Department of Town and Country Planning, 2010).

4.4 Savings in natural resources and restitution

Three alternative pavement types were studied (for the service road and stretches of main carriageway to be reconstructed) in terms of quantum and type of materials used viz., Conventional bitumen pavement with 19% recycled material (scarified bitumen) as option 1, Portland cement concrete pavement as option 2 and cement concrete with additives of fly ash (25%), slag cement (50%) and silica fume (25% along with Portland cement) as option 3. During construction, the third option was estimated to save 50% of granular sub-base (GSB) aggregates and; 8% or 10.32 litre/m of fuel; compared to the other options. During operation due to less deflation of tyres it would reduce 102.6 3 kl/year of fuel (American Concrete Pavement Association, 2007). Moreover, the third option can sustain longer as service road, despite of the liquid wastes from nearby villages getting accumulated on the road pavement. There are Indian Specifications available on use of Portland slag cement and fly ash-based Portland Pozzolona cement (Bureau of Indian Standards, 1990, 1991; Mullick, 2007).

Figure 5 Typical cross section of ground water recharge pit (see online version for colours)



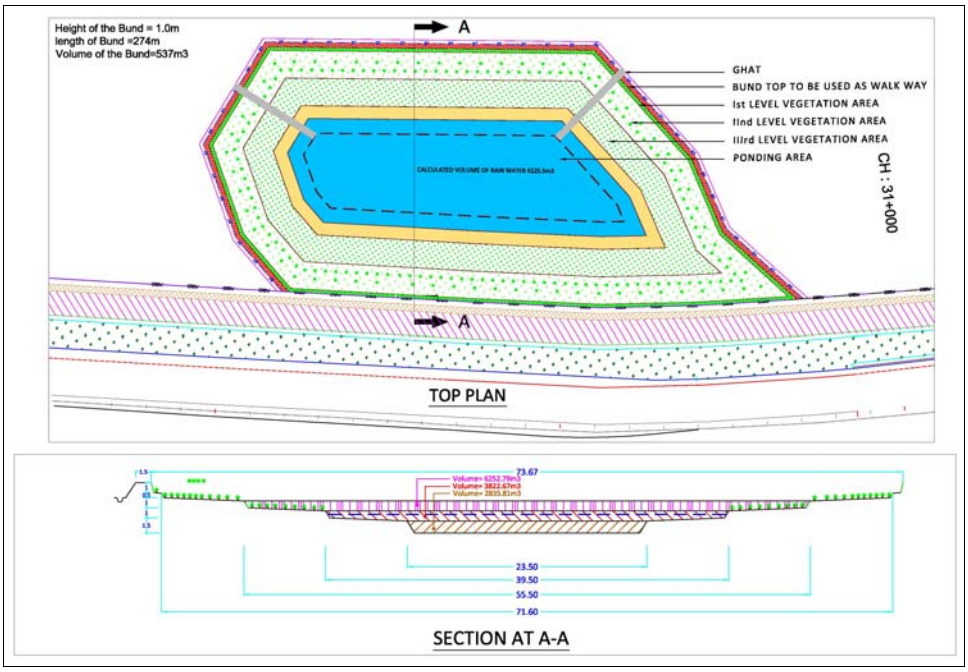
Amongst others, water is the most vital and scarce natural resource being used for construction and thus have been proposed for restitution. Ground water recharge is proposed through up gradation of five existing ponds to percolation ponds (designed to allow water to percolate into the aquifer by managing depth of the pond) and roof top harvesting in three government schools. Annually, these would be able to recharge around 21,708 m^3 and with this rate it would take around 11.9 years to compensate for 2.5 lakh KL water required during construction. Top plan and cross section for percolation pond is given in Figure 6.

4.5 Carbon footprint and air pollution reduction

Greenhouse gas emission estimation was done for the three alternative types of pavement using CHANGER, the GHG calculator developed by IRF. Materials used in option 3 generated 1.62 lakh tCO_2 eq. of carbon which is less than that of option 1 by 46%. Option 2 generates 2.17 lakh tCO_2 eq. that is less than option 1 by 28%. Option 3 shall reduce SOx, NOx emission by 62% and option 2 by 29% in comparison to option 1. During operation, option 3 could save 3,124.17 tCO_2 eq. of GHG per year (1.1% of vehicular emission); 32 tonnes of NOx and 4 tonnes of SOx per year based on fuel saving due to reduction in tyre deflation.

Saving in natural resource of fossil fuel-based grid connected power is possible by employing solar-LED application for street light. It can reduce GHG emission by 0.9% (254.9 tCO_2 eq.) of the total annual vehicular emission. It can also save Rs. 12.49 lakh per year of electricity bill.

Figure 6 Top plan and cross section for percolation pond (see online version for colours)



With the proposal of 11.5 m wide plantation strip along with BRS, carbon sequestration rate would increase from 0.211% in 2013 to 3.45% in 2045. It is lesser in the initial years as removal of vegetation would take place due to up gradation and that sequestration rate of newly planted ones would increase with their age until maturity. For creation of pollution sink along with that of carbon species with high Air Pollution Tolerance Index

(APTI) and also native to site are proposed viz., Azadirachta Indica or Neem (12.95), Cassia Fistula or Amaltas (10.87), Ficus Religiosa or peepal (10.36), Dalbergia Sisoo or seesam (9.91) and Eugenia Jambolana or Jamun (9.31) (Horaginamani et al.,2012).

4.6 Noise level attenuation

4.6.1 Off road treatment

The sensitive building uses in the first row without intervening land uses or vegetation cover have been considered for providing building treatment. Three schools that have been identified depending on the requirement and feasibility of attenuating noise are that of Rasoi at Km 34.400 (RHS), Bahalgarh at Km 40.700 (RHS) and Barhi at Km 59.000 (LHS). Noise level as calculated just before the boundary wall using formula (2) of the schools vary between 69 to 79 dB(A). Presently, unglazed brick wall boundaries exist along the schools that have absorption coefficient of 0.04, i.e., 4% of the incident noise would be absorbed by the given material. The height of the walls varies from 1.5 to 2 m. An assessment shows that carpeting of the existing walls by heavy (0.3 sound absorption coefficient) or light porous concrete (0.34 sound absorption coefficient) will help in reducing 30% and 34% of the incident noise on the wall. But since the structural condition of these walls is weak, carpeting may not provide a long lasting solution. It is recommended to demolish and reconstruct the existing boundary walls using Hollow block light concrete (0.34 sound absorption coefficient) with 200 mm thickness that will also reduce the noise level by 34% or 22 dB (A) on an average (Acoustical Surface Inc., 2014). Hence, the noise levels inside the boundary of the schools will get reduced by 21 to 24 dB (A). Hedges of 0.8 m above the walls have been recommended since it would also act as a pollution sink and add to aesthetics for the school goers.

$$L_2 = L_1 + 10 * Log10\left(d_1/d_2\right) \tag{2}$$

where

L_2 is the sound level at distance d_2

L_1 is the predicted sound level at distance d_1

d_1 is 1m from paved road edge

d_2 is distance of the boundary wall from road edge.

4.6.2 On road treatment

On road treatment have been proposed for Kundli, Bahalgarh, Gannaur and Samalkha flyovers where double storey residential receptors are present in the first row and second row of land use. Corrugated, solid, light coloured polycarbonate sheets shall be used preferably with 0.5 m width of clear sheet at the car driver eye level to provide a view of the commercial set up along the road. A light coloured sheet is preferred to avoid absorption of light during the night and hence not increase lighting requirement. A corrugated sheet is preferred to avoid the sun glare during the day time. The height of the noise barrier is suggested to be 1.8 m above crash barrier of 0.8 m thus cumulating it to 2.6 m. A height of 1.8 m is effective in reducing the noise level by 5 dB(A) because the view of moving vehicles getting cut acts as a psychological factor in reducing the noise.

Basically, the concept of out of sight out of mind gets applicable here. Each additional 1m height would reduce the noise level by 1.5 dB(A) and so the height of 2.6 m would reduce the noise level by 6 dB(A).

Amount of diffraction resulted by the top edge of the noise barrier is an important factor in reducing noise as well. The diffraction distance (δ) is calculated using formula (3) with source at the maximum height of 2.4 m for heavy vehicles at the centre of the carriageway and receptor at the height of 6 m, i.e., a double storey building roof with a lateral distance of 16.25 from the noise barrier. With the height of 1.8 m the diffraction distance is 0.213m and the corresponding noise reduction is by around 13 dB(A). Noise reduction is directly proportionate to diffraction angle represented by the distance (δ). To increase the diffraction angle, it is either required to increase the height or provide a half T or half Y section at the top. Out of both, the second option of providing tilted top is feasible and so the diffraction distance was calculated, with 0.3 m sheet projected on the road side (considering safety of moving vehicles), to be 0.34 m. This would lead to very less additional noise level reduction at a point where the line of sight or receptor point is lower but the additional reduction would be higher by 4 to 5 dB(A) [above 13 dB(A)] at points where receptor position is higher than that of the source. Hence, it is recommended to provide a tilt of 0.3 m in an angle of 124°.

$$\textit{Path length difference } (\delta) = R_1 + R_2 - R_0 \tag{3}$$

where

R_1 is the distance (m) from source height to top edge of the barrier

R_2 is the distance receptor height to top edge of the barrier

R_0 is the distance between the source and receptor.

The 12 mm thick polycarbonate sheet has a transmission loss (TL) of 33 dB(A) and noise reduction by 22 dB(A). Hence, 12 mm thick sheet shall be used for Kundli, Bahalgarh, Gannaur and Samalkha. Since providing one side barrier would increase the noise level by 2 dB(A) than the existing, it is always preferable to provide parallel barriers on opposite side of the flyovers and for an effective noise attenuation, the distance between the two shall be ten times the average height of the barriers. If the ratio of width to height is less than 10:1, then insertion loss degradation will be of > 3 dB(A). The barrier shall be gapless and continuous to avoid leaks, i.e., no gaps shall be there between the crash barrier and panels and also between panels (Federal Highway Administration, Department of Transportation, 2001; Ministry of Road Transport and Highways, 2010; Environmental Protection Department, 2003).

4.7 Solid and liquid waste management

As part of CSR activities the project proponent can facilitate the road side dhabas to maintain a hygienic condition. The project stretch has 32 dhabas along the road outside the RoW. Based on the distance and quantity of waste generation, they have been divided into four clusters. One Organic Waste Converter (OWC) shall be installed per cluster. Green and blue coloured bins shall be placed in each dhaba for effective segregation of bio degradable and non-biodegradable waste at source. The waste generated shall be collected every day or every alternate day and put into the OWC. The OWC would vary in capacity of 100 and 300 kg/day powered by solar energy with batching time of 20 minutes and curing time of 15 days. The area requirement would be 3 × 4 metre for the OWC and 40 to 150 m^2 of curing space. The OWC shall be placed in the biggest dhaba (in terms of waste generation) of the cluster and the curing space may be divided amongst the other dhabas. Curing may be done on multilevel trays to save on space. Capital cost may be borne partially by the project proponent and partly by the Dhaba associations formed by each cluster in collaboration with the local Solid Waste Management NGOs. The fertilisers can be sold off or given for free to the nearby villagers or used for road landscaping.

For liquid waste, bio-digesters invented by the Defence Research and Development Organization (DRDO) can be recommended individually for all the dhabas. Minimum dimension of tank required for use of six people daily is 1 m × 1 m × 0.7 m (Length × breadth × height) along with 0.9 m × 0.9 m × 0.9 m soak pit and area or numbers could be increased as per requirement. This would be able to treat 2 kg of solid waste, 20–30 litres of waste water producing 20 lts/day liquid fertiliser, one cum of biogas (equivalent to 0.5 kg Liquefied petroleum gas). The fertiliser generated can be used or sold and biogas produced can be used for cooking. Project proponent may pay the capital cost of installation under CSR activity.

5 Cost of greener interventions

Unit cost worked out for LID BRS is Rs.1.29 crore per kilometer, recharge pit is Rs. 0.06 crore per pit, solar-LED street light is Rs. 30,000 per pole, polycarbonate sheet as noise barrier is Rs. 5,000 per running meter, hollow concrete blocks as noise barrier is Rs. 2300 per running meter, percolation pond is Rs. 15 lakhs per pond, roof top RWH is Rs. 3 lakhs per structure, Rs. 30,000 per bio toilet, Rs. 4 lakhs per OWC and Rs. 1.8 crore per kilometer for cement concrete pavement with additives. Cost of the project with greener interventions is Rs. 25 crore per kilometer that is calculated to be 1.3 times higher than that of conventional type or without greener intervention. Though the cost is higher than that of conventional type but the benefits in terms of environment would be much higher.

6 Conclusions

As found from this study, LID-BRS and RWH pit can increase storm water tapping capacity up to 80%, diverting 33% of it for ground water recharge. The BRS plantation can increase carbon sequestration up to 3.45% by 2045 against 0.211% in 2013. A material combination of cement concrete with additives can reduce granular sub base aggregate requirement by 50%, save fuel by 8%, reduce GHG emission by 46% and NOx, SOx emission by 62% compared to that of conventional asphalt or cement concrete pavement during construction. During operation also this pavement type can reduce GHG emission by 1.1% of annual vehicular emission. Opting for solar Light Emitting Diode (LED) streetlights can help reduce GHG emission by 0.9% of the annual vehicular emission besides saving around 12.5 lakhs on electricity bill per year. Provisions of percolation ponds and roof top RWH is estimated to compensate 2.5 lakh KL of water used for construction in 11.9 years.

The interventions for greening the roadways as discussed above can be customised to fit into up gradation of existing or construction of green field roadways. A simultaneous multiple approach (SMA) solution is inevitable in addressing the issues of greenness as a roadway cannot be taken in isolation from the surrounding land uses. However, these interventions are maintenance intensive and require dedicated and collaborative involvement of all the stakeholders, especially the road authority, local administrative bodies, design consultant and contractors. In addition involvement of local people at the design stage and maintenance activities could lead to successful execution of SMA.

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